THE KYIV MERIDIAN AXIAL CIRCLE WITH A CCD MICROMETER

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The Kyiv meridian axial circle (MAC) is a refractor ($D = 0.18$ m, $F = 2.3$ m) which is used now in a CCD astrometric survey of the equatorial zone. In 2001, it was equipped with a ISD017AP CCD having 1040×1160 pixel, 16 mkm pixel size, and 1.394″ per pixel scale. The dark current is $7e^-$/pixel/s, the readout noise is $18e^-$, the output amplifier responsiveness is 3.3 $\mu V/e^-$. The photometric system of the MAC reproduces standard V photometric system; the limiting magnitude is about $V = 17$. Star pixel coordinates are measured with an accuracy of 0.02 pixel and star fluxes to 0.02 mag. The frame size is $24' \times 28'$. Observations are obtained in the drift-scan mode allowing to form images of moving objects at telescopes without the moving parts. Exposure time is $108 \sec\delta$ s while the scan length may reach hours. Observed data are stored on CD disks. It was estimated that image degradation for this CCD micrometer owing to CCD distortion amounts to $4.9'' \tan\delta$ in right ascension and $1.2'' \tan\delta$ in declinations, therefore, the declination zone of observations was limited to 30 degrees. A special software is used for reduction of observations.

INTRODUCTION

In 2000, the Kyiv meridian axial circle (MAC) has been equipped with a new modern micrometer based on a CCD image sensor and manufactured at the Nikolaev Astronomical Observatory [1]. Since 2001, after necessary tests of electronics and the matrix quality, the telescope has been used for program observations.

Owing to application of a new detector, the telescope can be used for the solution of various problems of modern astronomy, especially concerning those where high-precision measurements of celestial object positions and photometric characteristics are required.

Observations at the MAC are performed by group of astronomers from the Astronomical Observatory of Kyiv National University and from the Main Astronomical Observatory of the National Academy of Sciences of Ukraine. The instrument is being used for extending the Hipparcos–Tycho reference frame in the two observational projects. In 2001–2003 years, a pilot program of observations of stars in 192 fields with extragalactic ICRF sources in the declination zone from 0° up to +30° had been performed; these observations formed the basis for compilation of a catalogue of positions, photometric data and proper motions of 115 000 stars. The second, long-term project is the astrometric survey of the sky in equatorial zone from 0° up to +5° to obtain astrometric and photometric data for faint stars in the V photometric band.

THE TELESCOPE

Schematic arrangement of principal optical, mechanical and electronic modules of the MAC telescope is shown in Fig. 1.

The telescope tube (5) is placed horizontally in the first vertical and may rotate in two high-precision ball-bearings. Directly at the two-lens objective ($D = 180$ mm, $F = 2335$ mm) of the telescope (3), at 45 degrees to its optical axis, a flat mirror (2) is mounted safely. A 35 mm round hole is made in the mirror center. Behind of the hole, a reference light source (1), used for tests of a CCD, is installed. Micrometer module is mounted on a straight-through flange (6). Micrometer contains the glass filter unit (8), pre-amplifier (9), and a CCD matrix module. The mechanic fastening, together with a straight-through flange (6), are manufactured so that to allow adjusting movements of the CCD along three directions, rotation around the optical axis including.

The CCD matrix unit (10) with a cooling element (11) are manufactured as a single module fastened to the radiator (12).

The cooler is a two-stage semiconducting Peltie thermoelement that provides a temperature difference "matrix – environment" up to 40 degrees.

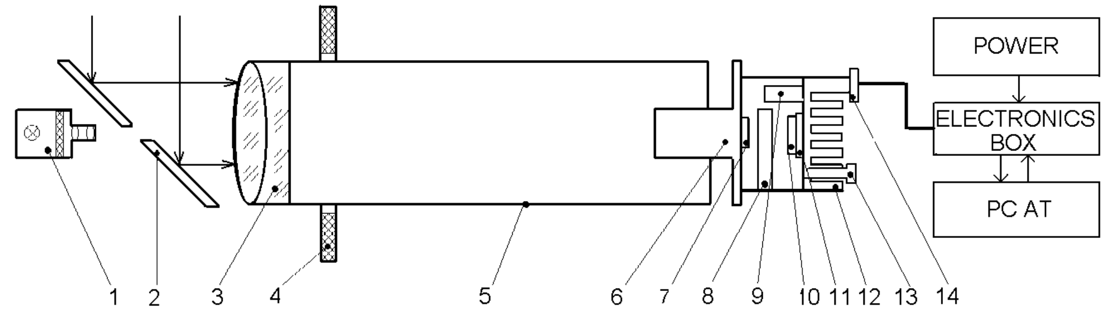

Figure 1. The module structure of a telescope MAC: 1 – reference light source; 2 – diagonal mirror; 3 – two-lens objective; 4 – divided 5′ glass circle; 5 – tube; 6 – straight-through flange; 7 – front window of the micrometer; 8 – glass filter box; 9 – pre-amplifier; 10 – CCD matrix unit; 11 – Peltie cooling elements; 12 – radiator; 13 – silica gel box; 14 – connector

The micrometer is based on a ISD017AP CCD device with a virtual phase, manufactured by Electron–Optronics, St.-Petersburg. It contains 1040×1160 pixel; some basic features of a CCD are given below in Table 1.

Table 1. Basic features of the CCD

Number of unit pixel ($H\times V$)	1040×1160
Organization of the device	SFF
The size of a pixel, micron	16×16
The photosensing area, mm	16.6×18.6
Saturation charge, thousand el.	130
Readout noise, el.	18
Dark signal ($T=-40°$C), el/s/pixel	7
Conversion coefficient, μV/el.	3.3
Non-uniformity of sensitivity, %	3
Inefficiency of a charge transfer	
– along horizontal direction	$1.5\cdot10^{-5}$
– along vertical direction	$1.1\cdot10^{-5}$
Quantum efficiency, %	
– at 250 nm	12
– at 400 nm	25
– at 750 nm	60
– at 1000 nm	8

THE MODES OF OBSERVATIONS

A telescope can operate in the two modes. In the first, direct imaging mode, a light signal from the sky forms charge packages simultaneously in all CCD pixels. Exposure length is controlled by a program; a fast reading of the data is performed when the observation is finished. A range of usable exposures is limited only by background and (or) dark current. This mode is used for observations of static images, mainly for testing purposes.

In the second, scan-drift mode, accumulation of charge packages is synchronized with star image motion along the CCD. In this mode accumulation of a signal in CCD pixels occurs synchronic with its transfer along columns of a matrix. The rate of charge packages transfer is taken to be equal to the speed of image motion along the matrix. In this mode an angular size of the observed sky area on declination is determined by the angular size of a CCD and is equal to 24.2′. The scan length on right ascension is unlimited.

OBSERVATIONS AND DATA STORAGE

Observations on the MAC are not completely automatic since there is no system of the telescope setting on a zenith distance. However, after being set at a necessary zenith distance, the telescope and observational process are fully controlled by computer and do not require any human intervention.

Table 2. Characteristics of the Kyiv meridian axial circle

Entrance pupil	180 mm
Focal length	2335 mm
Photometric band	V (Johnson)
Scale	$1.394''$/pixel
Limiting stellar magnitude	$V = 17$ mag
Modes of observations	direct imaging and scanning
Direct imaging:	
	Frame size: $24.2' \times 28'$
	Exposure: 0.01–1000 s
Scanning:	
	Scan width in declination: $24.2'$
	Exposure: $108 \sec\delta$ s
Declination zone	$0° \div +30°$

Original information coming from a CCD in the process of observations is saved on a hard disk. Depending on the program of observations, the data is recorded either directly on a hard disk, or after provisional saving to the computer random access memory (RAM). The first version of a data recording is normally used for observations under a program of the astrometric survey of the equatorial sky area, when scans are very long (to several hours). The second version requires considerable resources of RAM, which therefore restricts a maximum scan length. This mode was adopted for observations in rather narrow (up to 1 degree) fields, for example, with extragalactic radio sources or some single peculiar objects. After each night of observations the scans obtained are achieved and saved on CD-ROM.

Observations of celestial objects at this telescope are performed in a declination zone from 0° up to +30° since, due to incomplete compensation of star image motion along a matrix at synchronous transfer of charge packages, the measured star images become degraded. Smearing in declination direction arises because the projection of a diurnal parallel to a matrix plane has a form that deviates slightly from a straight line; in right ascensions the effect is caused by a difference of apparent speed of stars with extreme declinations in the field from that at the central clocking declination. For this telescope, a maximum value of smearing is $4.9''\tan\delta$ in right ascensions and $1.2''\tan\delta$ in declinations. Under limitation $\delta < 30°$, the effect does not exceed $2.8''$ and $0.7''$ in right ascensions and in declinations, respectively, which is quite acceptable.

[1] *Telnyuk-Adamchuk V., Babenko Yu., Lazorenko P., et al.* Observing programs of the Kyiv meridian axial circle equipped with a CCD micrometer // Astron. and Astrophys.–2002.–**386**, N 2.–P. 1153–1156.